International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 9, Issue 1, Feb 2019, 483-494

INVESTIGATING THE ENERGY AND EXERGY ANALYSIS IN COAL FIRED POWER PLANT

REZA FATHOLLAHI[1] & AGIL FAZELI[2]

[1]*Department of Mechanical Engineering, Engineering Faculty of Khoy, Urmia University, Urmia, Iran*

[2]*Department of Mechanical Engineering, Faculty of Engineering, Islamic Azad University of Khoy, Khoy, Iran*

ABSTRACT

Increasing growth in energy demand has already made its importance in the last century. Due to the large contribution of fossil fuels to world energy, it is almost impossible to replace the fossil fuels with other energy resources in the near future. However more no of power plant are placed, where 75% of power is generated by burning coal. According to high energy cost and necessity to reduce it, optimal use of energy and energy consumption management are very important.

So the research purpose is analysis of energy and exergy in coal fired plant was carried out, then the initial goals of present research are to assess the plant parameters singly and to determine and measure the coal plant with largest losses for energy and exergy. However, analyses of energy and exergy have been performed for coal plants like boiler, turbine, and condenser and pump majorly.

The results reveal that the reduction in the efficiencies of energy and exergy is comparatively tiny. The symmetry among losses of the energy and the exergy for the parameters of the plant separately revealed that the peak of losses of energy (75%) take place in the condenser, so that the peak of losses of exergy (82%) take place in the boiler. So, to obtain major increase in energy efficiency, the condenser and boiler systems required to be changed, that require more techno-economic research.

KEYWORDS: Energy Analyses, Exergy Analyses & Coal Power Plants

Received: Dec 12, 2018; **Accepted:** Jan 02, 2019; **Published:** Jan 24, 2019; **Paper Id.:** IJMPERDFEB201947

Original Article

1. INTRODUCTION

Electrical energy is universal energy that may be turned various kind of energy, and so the need for electric energy is increase in worldwide. However many of plant are not placed, where 75% of power is generated by burning coal.

The maintain process of energy in coal plant considered as one of the vital factors to decrease the speed of use of fossil fuel, via sharp developing of civilization use of energy is also enhancing quickly.

According to high energy cost and necessity to reduce that, and environmental problems, optimal use of energy and energy consumption management are very important. In this regard, we require data analysis tool that we may find in two laws of thermodynamic [1].

The analysis of energy focused on first law of thermodynamic that irreversibility of the systems is not determined, and features of power plant or decrease of energy quality is not examined.

The actual effective losses of energy cannot be specified via the fist law of thermodynamics, since there is any different among the characteristic and extent of energy [2].

The analysis of exergy focused on second law of thermodynamics. The exergy of power plant allows determining the irreversibility's in the production process and to determine this for plants and the reason that affect the total efficiency [3].

The energy-exergy analysis has been performed for components of coal plant like the boiler, turbine, and condenser and pump. The result of thermodynamic analysis is determined in terms of 24.12% energy efficiency of plant, 35% exergy efficiency of plant and 11% energy efficiency of boiler respectively. The various exergy losses in the parameters of coal plant have been shown [4].

Husnain et al (2017) carried out a study under analysis of exergy and energy in plant station Muzaffargarh in Pakistan aimed to investigating the plant with maximum losses of exergy and energy in the system. The result shows that highest energy losses can be seen in the condenser system was lost in the environment.

The percentage proportion of inalterability for the boiler system is 84 % and 9% of the condenser system. The efficiency of energy specified according to the fuel less heating amount is presented 34%, and the efficiency of exergy for power performance is 32% [5].

Rajper et al (2016) in a study examined the analysis of thermodynamic 210 MW dual-fires, below a critical threshold, heat again plant that run with steam placed near Jamshoro, Pakistan.

The results of study revealed that the net value of power outlet, the efficiency of energy and the efficiency of exergy determined equal to 186.5 MW, 31.37% and 30.41%, respectively. The main region of exergy destroys for boiler, turbine and condenser was 350 MW (82.11%), 43.1 MW (10.12%) and 12 MW (5.74 %), respectively. Considering the finding of parametric research, change in operating components had more effect on the function of plant [6].

Hafdhi et al (2015) conducted a study on analysis of energy and exergy in a steam plant for phosphoric acid factory. The heat recovery systems used in the different parts of the plant are also considered in the study. The balances of exergy and energy produced based on the major components of the plant. The influence of components examined on the function of plant. The efficiency of exergy for the heat exchanger was 88%, the efficiency of exergy for the steam turbine generator was74%, the efficiency of exergy for the deaerator was 72% and the efficiency of exergy for the blower was equal to 66%. The impacts of high pressure steam temperature and pressure on the steam turbine generator in term of efficiency of energy and exergy are investigated [7].

Olaleye (2015) in a study examined the exergy of coal plant and steady state simulation. This study show that development in function of turbine and the motive power accountable for CO2 capture lead to enhance the efficiency of the plant [8].

Kumar et al (2014) performed a study entitled thermal performance and economic analysis of 210MWe coal-fired power plant in North India. The plant examined in term of the consumption rate of coal, thermal efficiency, steam flow rate in boiler, and Net Present Value (NPV) of plant. The economic analysis consisted of operational functions including the cost of device, the cost of combustion, the cost of function and conservation, income, and Net Value of system.

Economic believed that the effect of condensed exploitation pump amplitude in term of NPV is permeable than feed pump amplitude of boiler [9].

Gulhane J Sarang et al (2013) have found the value and original of inalterability in the boiler of power plants. They have also determined that maximum losses of energy occurred in part and it lead to developed the plan of that part [10].

Pal K. M. et al (2013) have recommended that the real inalterability of various parts of the plant can be computed in term of the analysis of energy and exergy. They have concluded that actual evaluation of the plant can be carried out via analysis of exergy. This study examined the analysis of exergy of different components of plants and creates various curves [11].

2. SYSTEM DESCRIPTION

Present study carried out on coal plants, and schematic diagram of coal plant is shown in Figure 1. Coal fired plant use major parts of plant at high, medium and down pressure boiler, turbines, deaerator, pumps, condenser, generator, up and down pressure for heaters feed water etc.

At full load condition parameter reading is noted down. In this regard the entropy and enthalpy amount is denoted from the table of steam. Analysis of energy and exergy is determined for every parts of the coal plant. The destruction of exergy is determined for every section and losses are calculated according to position and value. The efficiency of energy and exergy estimated and to determine the losses in coal fired plant parts.

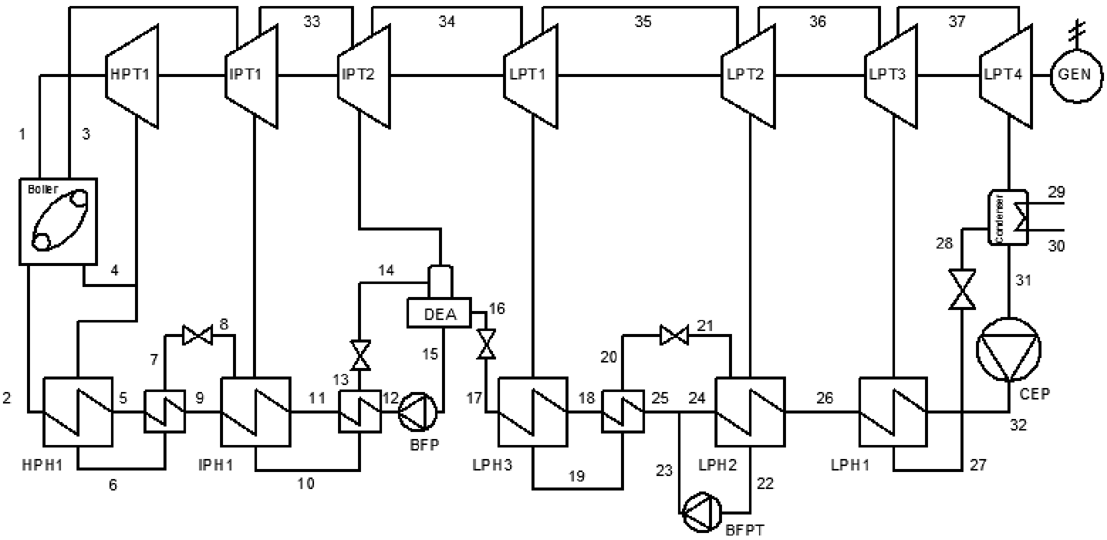


Figure 1: Schematic Diagram of Coal Fired Plant

Steam is expanded in high, intermediate and low (HP, IP and LP) pressure turbine and power is connected to the generator (GEN) that placed after the last low pressure turbine (LPT4). Steam flows for turbine with pressure at high level with high energy and exergy going to boiler for reheating with low energy and exergy.

Hot reheat steam flows passing to turbines such as IP and LP respectively. The condensed steam is pumped to going to the 3 pressures at low level for feedwater heaters and deaerator.

Upper terminal temperature difference (UTTD) utilized impregnation temperature at the exploitation pressure and the temperature of water at the heater output. This temperature was constant at all feedwater heaters within the cycle. The DEA is an FWH that applied elicited steam such as closed feedwater heaters. So, other pump is needed due to the pressure output which is not higher than the pressure of the elicited the steam. In order to have best performance in exchange, the control amount has to applied pressure at low level. The boiler considered as an open exchanger with pressure at low level that the fluid lead to increases the temperature of that in order to enter into turbine phases. GEN efficiency is considered for thermal efficiency calculation.

3. THERMODYNAMIC ANALYSIS

In this part, the exergy approaches are presented to analysis the exergy destructions and potential for efficiency for coal fired plant. To calculate the coal fired plant efficiency, the control volume is examined (Figure 1). In this study, analysis of exergy for various parts of coal fired plant carried out. The exergy is a criterion of the utmost amount of a system to carried effective study as it exceed to a special ultimate mode in balance.

The exergy is fundamentally not utilized as energy but also destroyed in the coal fired plant.

The destruction of exergy calculated in term of inalterability which is base of efficiency loss. So, an exergy analysis calculating value of exergy destruction determines the location, the amount and the original of inefficiencies of thermodynamic in a plant. The balances of energy, mass and exergy for each control amount at ready mode with negligible potential can be expressed:

For each control volume amount at ready mode, the balance of exergy amount is given as

$$\sum_i m_i = \sum_o m_o \tag{1}$$

The balance of energy for a control amount of plant is given as follows

$$\sum_i \dot{E}_i + \dot{Q} = \sum_o \dot{E}_o + \dot{W} \tag{2}$$

The balance of entropy for the amount of plant is equal to

$$\sum_i \dot{S} + \sum_i \frac{\dot{Q}}{T} + \dot{S}_{gen} = \sum_o \dot{S} + \sum_o \frac{\dot{Q}}{T} \tag{3}$$

The balance of exergy for control amount of plant is given as follows:

$$\sum_i \dot{E}x_i + \sum_k (1-\frac{T}{T_k})\dot{Q}_k = \sum_o \dot{E}x_o + \dot{W} + \dot{E}x_d \tag{4}$$

So the exergy amount of a flow is:

$$\dot{E}x = \dot{m}(ex) \tag{5}$$

$$\dot{m}(ex) = \dot{m}(ex^{tm} + ex^{ch}) \tag{6}$$

The balance of exergy at high level is given generally. For the process of combustion, as the exergy of fossil fuels is calculated, the inlet temperature must also be calculated. The expression of thermal exergy in Equation 4 applied to estimate the losses of exergy along with the thermal losses transferred to the environment. Special exergy could be estimated via the below equation.

$$ex^{tm} = (h-h_o) - T_o(s-s_o) \tag{7}$$

When combustion occurs in a boiler, coal is burned and carbon dioxide, water vapor and other combustion products are produced. The combustion reaction that describes combustion of coal with theoretical air is:

5.8C + 2H2 + 6.08 (O2 + 3.76N2) = 5.8CO2 + 2H2O + 22.86N2 (8)

With the assumption that the boiler will work with 20% of the extra air, the combustion reaction will be as follows:

6.29C + 2H2 + 7.29 (O2 + 3.76N2) = 6.29CO2 + 2H2O + 27.41N2 (9)

Based on unit per mole based on carbon, the relation is as follows:

C + 0.32H2 + 1.16 (O2 + 3.76N2) = CO2 + 0.32H2O + 4.36N2 (10)

The Exergy balance equation for the reaction [12] is equal to (Moran and Shapiro, 2006):

$$\sum N_p(\bar{h}_{fo}-\bar{h}-\bar{h}_o-T_o\dot{s})_p = \sum N_r(\bar{h}_{fo}-\bar{h}-\bar{h}_o-T_o\dot{s})_r \tag{11}$$

Exergy of gas for the carbon mass of gas is illustrated by equation 12.

$$Ex_{GT} = \frac{(Ex_{reaction} \times \eta_c \times \eta_f)}{M_c} \tag{12}$$

Then, the efficiency of exergy and energy in the plant are given as follows:

$$\eta_{exergy} = \frac{W_{output}}{Ex_{GT}} \tag{13}$$

$$\eta_{exergy} = \frac{W_{output}}{m_f \times C_v} \tag{14}$$

Table 1: Definitions of the Destruction Rate of Exergy and the Efficiency of Exergy in Plant

	Exergy Destruction Rate	Exergy Efficiency
Boiler	$\psi_{boiler} = \frac{Ex_e - Ex_i}{Ex_f}$	$\dot{I}_{boiler} = Ex_f + Ex_i - Ex_e$
Pump	$\psi_{pump} = 1 - \frac{I_{pump}}{W_{pump}}$	$\dot{I}_{Pump} = \dot{W}_{pump} + Ex_i - Ex_e$
Heater	$\psi_{heater} = 1 - \frac{\dot{I}_{heater}}{Ex_i}$	$\dot{I}_{heater} = Ex_i - Ex_e$

Table 1: Contd.,		
Turbine	$\psi_{turbine}=1-\frac{\dot{I}_{turbine}}{Ex_i-Ex_e}$	$\dot{I}_{turbine}=Ex_i-Ex_e-\dot{W}_{turbine}$
Condenser	$\psi_{condenser}=\frac{Ex_e}{Ex_i}$	$\dot{I}_{condenser}=Ex_i-Ex_e$
Cycle components	$\psi_{cycle}=\frac{\dot{W}_{net,out}}{\dot{X}_{fuel}}$	$\dot{I}_{cycle}=\sum_{\text{all component}}\dot{I}$

4. RESULTS AND DISCUSSION

In this section, results are presented and discussed relating to plant efficiency and so a parametric study is presented to elaborate the impact of operating components on the plant function. In the parametric research, net power value, efficiency of energy and efficiency of exergy are taken as performance parameters while the pressure of condenser, major pressure of steam, boiler and main steam temperature are determined as operating parameters.

4.1 Energy and Exergy Performance

The model of the coal power plant is modeled to determine various thermodynamic values at whole state modes in Figure 1 and is tabulated in Table 2. Moreover, some constant parameters are adopted from the "thermodynamic performance" [13] heat balance sheet at Economical Continuous Rating (ECR) condition (583250 Nm^3/hr and 48400 kg/h) provided by the power plant authorities. The evidence was prepared via producer at the period of plant operating at utmost 200 MW loads.

Table 2: State Point Values at Different Locations of Coal Fired Plant

Point	Pressure (bar)	Temperature (°C)	Enthalpy (kJ/kg)	Mass Flow (kg/s)	Flow Energy (kW)	Vapour fraction	Entropy (kJ/kg.K)	Exergy (kJ/kg)	Flow Exergy (kW)
1	31.4	415.3	3878.1	55.3	254996.1	0.987	6.548	1235.88	9875.55
2	25.3	378.2	3769.4	51.9	98654.9	0.987	6.456	1498.01	6489.32
3	8.8	321.21	3624.9	48.3	65478.9	0.987	6.012	1097.25	4885.12
4	7.12	221.0	3249.1	32.6	35894.2	0.987	6.967	978.97	8976.89
5	2.03	88.9	2988.9	29.7	45899.6	0.987	6.328	805.28	1012.37
6	1.04	51.7	2877.6	22.6	64589.9	1.012	6.105	659.837	1124.64
7	0.025	32.6	2567.3	156.9	457856.9	1.018	7.001	841.84	976.41
8	220	579.4	3467.1	398.4	124585.3	0.000	5.457	1475.25	1646.45
9	278.14	287.0	2415.9	388.7	698785.3	1.000	5.369	325.36	467854.2
10	38.65	568.0	3546.7	396.1	33258.9	0.007	6.348	2345.9	54783.9
11	89.351	367.8	3745.1	402.1	124445.9	1.000	3.235	1889.5	1646.02
12	227.89	221.7	994.2	411.9	854639.0	0.000	3.965	256.9	45786.4
13	33.8	296.6	1022.9	45.8	734291.3	0.000	2.154	345.9	9566.75
14	33.8	207.4	987.65	45.8	963358.8	0.002	2.158	314.7	4573.02
15	19.45	238.4	987.65	45.8	445260.7	0.009	2.987	349.8	65894.39
16	227.89	241.9	897.6	366.5	88475.6	0.001	2.367	245.6	35968.22
17	18.9	278.9	902.5	58.3	352659.1	0.000	2.864	247.9	12489.04
18	17.22	204.9	887.4	41.6	36941.6	0.007	2.404	230.69	9603.34
19	209.76	201.9	869.4	406.4	353330.2	0.000	2.320	235.69	95786.62
20	17.22	204.9	874.7	66.2	57901.4	0.000	2.377	225.26	14910.36
21	209.81	168.0	722.1	406.4	293461.5	0.000	1.998	176.24	71625.39
22	209.86	161.7	694.9	406.4	282412.0	0.000	1.936	166.01	67468.29
23	17.22	167.3	707.8	66.2	46852.0	0.000	2.014	157.64	10434.80

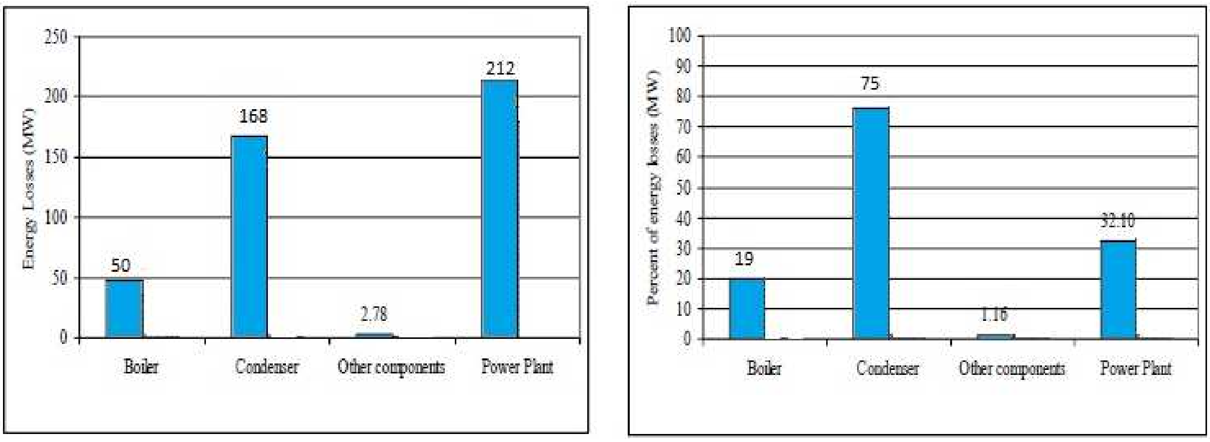
Table 2: Contd.,

24	5.74	157.1	707.8	66.2	46852.0	0.021	2.018	156.52	10360.25
25	5.74	157.1	663.0	406.4	269460.0	0.000	1.914	140.16	56963.47
26	5.74	118.5	497.6	319.1	158804.8	0.000	1.511	84.77	27051.50
27	16.99	118.3	497.6	319.1	158804.8	0.000	1.508	85.60	27316.57
28	17.48	92.1	386.9	319.1	123473.9	0.000	1.215	54.89	17514.89
29	2.07	121.3	509.3	14.3	7780.4	0.000	1.542	88.06	1345.26
30	2.07	97.8	401.6	14.3	5789.1	0.000	1.260	57.46	877.68
31	0.8	98.5	401.6	14.3	5789.1	0.004	1.260	57.33	875.83
32	0.8	98.5	391.6	34.5	13516.1	0.000	1.233	54.79	1890.85
33	17.53	98.7	393.8	34.5	13591.0	0.000	1.234	56.64	1954.61
34	17.53	91.5	380.3	284.6	108237.6	0.000	0.000	53.23	15150.22
35	17.53	91.8	381.8	319.1	121828.6	0.000	1.201	53.60	17103.47
36	18.02	53.6	228.9	278.6	56485.1	0.0012	0.749	21.15	6019.59
37	0.18	89.5	128.9	5.9	1073.5	0.012	0.845	20.99	87.22

Energy and exergy flow rates, energy and exergy rejection rates and exergy consumption and exergy destruction rates for the total turbine cycle are estimated from the plant's performance information for operating area presented to have better function: utmost load with outlet. The properties of operational thermodynamic for different coal plant are shown in Table 2.

Thermal efficiency is the proportion of output of pure electrical energy (32.1%) to input of coal energy (33.1%). Obviously, the efficiency is relying on certain input of heat to the steam. The balance of energy reveals that 75% of the energy summed to boiler is destroyed in the condenser and surroundings, so the amount destroyed in the boiler is only 19%.

However, efficiencies of energy returned non-intuitive due to a criterion of spirituality of conversion of energy is not prepared. Major losses of energy have a huge amount, however it's thermodynamic is down, so if estimate it for energy with low amount. In other word, efficiencies of exergy and destruction of exergy or entropy reveals a criterion to process spirituality or separated from spirituality, and then a criterion of energy amount. The losses of energy for different parts are determined in Figures 2(a) and 2(b).



a) Energy Losses for the Plant Components **b) Percent of Energy Losses**

Figure 2: The Losses of Energy for the Parts of Coal Plant

Second law efficiency, exergy and percent of destruction of exergy for different parts of coal plant are presented in Figure 3. It is shown that the destruction value of exergy for boiler compared with whole other inalterability place in the

coal plant.

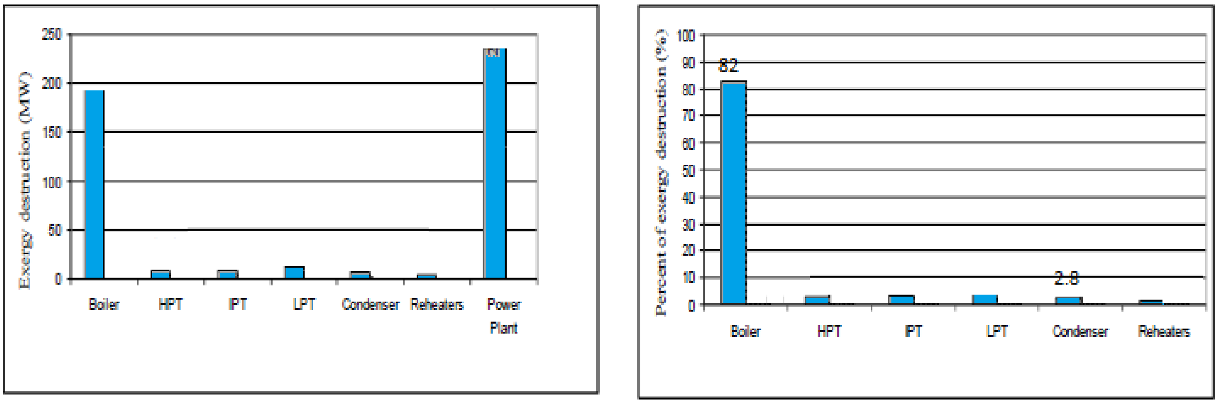
The destruction value of exergy of boiler 82% of total losses in the coal fired plant. In addition, destructions of exergy in the condenser were equal to 2.8%. The reasons for this are inalterability intrinsic in the process of combustion, loss of heat, and imperfect combustion and losses of exhaust. Moreover, we can say that the boiler needed to some necessary modification for reduction of destructions of exergy and improve the plant performance.

In addition, the losses of energy in the condenser cannot be actually applied to reach a development in the outlet of the plant, due to its low amount.

This may be the findings of the plants age, or the fact that it is not operating completely in design conditions. We can deduce that significant opportunities are available for efficiency improvement. Inherently, some inalterability cannot be denied because of constraints in physical, technical, and financial aspect.

The analysis of exergy in coal fired plant show that the improvement in the boiler can increase the total efficiency of power plant. It is clear that the major issues in the terms of losses of energy and destruction of exergy are the condenser the boiler. Since redesign of the boiler for further total efficiency improvement would be difficult, expensive, and possibly not even feasible, it has come to our attention that further improvements should be investigated in the direction of integration with another process.

The total efficiency of energy was equal to 30% and efficiency of exergy was equal to 40% for the plant ([14], [15] and [16]), that match with the findings reach for the Kolubara plant.



a) Exergy Losses for the Plant Components **b) Percent of Exergy Destruction**

Figure 3: Exergy and Percentage of Destruction of Exergy

The efficiency of exergy as second law efficiency for different parts is obtained and their comparison is drawn in Figure 4.

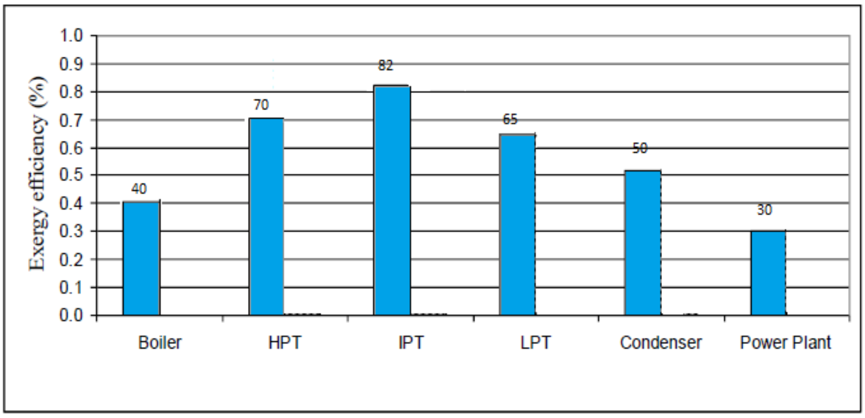


Figure 4: Efficiency of Exergy

The efficiencies of exergy of the plant for HPT are equal to70%, for IPT 82% and for LPT 65%. The efficiency of exergy for the boiler and the condenser obtained 40 and 50%, respectively.

The analysis of energy in the plants reveals that the positions with maximum energy are destroyed in the surrounding. Analysis of exergy indicates that the positions in the plants with maximum process of inalterability, preparing the data concerning the amount of energy exchange. Indeed, analysis of exergy indicates the eventuality for development, with a constraint that some inalterability is unavoidable as specified by the second law of thermodynamics.

In this study, analysis of energy and exergy in coal fired plant showed that the plant parts separately analyzes to determine and quantify the positions with the maximum losses of energy and destruction of exergy.

Analysis of energy in the plants in term of the first law of thermodynamics reveals that the maximum losses of energy occurred in the condenser. However it concluded by the first law of thermodynamics that analysis of energy, cannot be used to show prospective areas for enhancing the efficiency of plant, since it does not show the data concerning the amount of the energy losses.

Moreover, the second law analysis applied to determine the inalterability in the plant, show the data concerning energy amount to produce energy. The analysis of exergy in the plant revealed that the losses of energy in the condenser are thermodynamically trivial because of low amount and maximum inalterability and eventuality for development of efficiency seen in the boiler.

However, some inalterability cannot be denied because of constraints in physical, technical, and financial aspect. The analysis of exergy in term of function and preservation decision-making in coal fired plant confirmed more useful. Plant consisted of a high level of exergy, so enhancing the importance of destruction in such plant to at least probable level. Controlling exergy in performance of plants leads to better function of both energy and exergy resources.

5. CONCLUSIONS

In this study, the analysis of energy and exergy in coal fired plant is performed. So the research purpose is analysis of energy and exergy in coal fired plant was carried out, then the initial goals of present research are to assess the plant parameters singly and to determine and measure the coal plant with largest losses for energy and exergy.

This study elaborates the method for analysis of energy and exergy in a coal fired plant. It is deducted that analysis of energy and exergy are effective for determining the function of a coal fired plant.

The losses of energy at different parts of plant are estimated and we can specify that significant loss take place in the condenser (75%). These findings rely on first law of thermodynamics. The significant destruction of energy takes place in the condenser which led to inefficient heat transfer among flue gas and water and air.

The analysis of exergy on major parts of coal fired plant are performed, so we can determine the significant loss of energy which is takes place in the plant are estimated via condenser, even though significant loss of energy are in condenser and but significant loss of energy are in boiler (82%). Indeed the findings are more accurate. So the condenser, boiler is redesigned to reduce the heat loss and better heat transfer in boiler, and by redesigning the condenser.

The symmetry among losses of the energy and the exergy for the parameters of the plant separately revealed that the peak of losses of energy (75%) take place in the condenser, so that the peak of losses of exergy (82%) take place in the boiler.

The efficiency of plant parts is estimated via estimation of energy and exergy. We can observe that the loss of efficiency in condenser and boiler is compared to other plant parts; indeed we should enhance the efficiency of boiler and condenser by redesign and reconstruction. However the percent of loss in condenser is more the quality of the energy is not good. Hence scope of saving energy is more in these components.

It has been seen that losses of exergy takes place in boiler. This refers to boiler is not perfectly adiabatic and combustion is not perfect. This huge amount loss of exergy is basically due to the combustion reaction and to the huge temperature difference among heat exchange between the combustion gas and steam. Other aspects that may apply to the huge value of exergy loss including fuel amount, tubes fouling, defective burners, incompetent soot blowers and etc. investigating of this device require to be performed during the boiler outlet. This study shows that the boiler need necessary modification to decrease destructions of exergy by plant function can be developed.

The analysis of exergy of plant specifies the region that most of the effective energy is destroyed and elaborates the probable of the energy losses for enhancement of efficiency of energy in coal plant.

It shows that the condenser and boiler of a plant is the main original of effective loss of energy. From final analysis of boiler it could be deducted that perfect combustion takes place but because of high pressure of air, fuel consisted fines that flies with flue gas and burns at the above of boiler by enhancing the temperature of upper heater and exiting the boiler at upper temperature.

However losses in condenser are higher than the amount of energy; indeed we have to focus on boiler and condenser to enhance the plant efficiency.

Only negligible amount of effective losses of energy can be recovered by performing other heat recovery plant. In order to achieve significant improvement of energy efficiency the condenser and boiler systems need to be altered and redesigned, which need more techno-economic research.

REFERENCES

1. *Satish V., Dhana Raju V., Energy and Exergy Analysis of Thermal Power Plant, International Journal of Engineering Science and Computing, Volume 6 Issue No. 8, 2018.*
2. *Ravi Kulkarni H., Revankar P.P., Hadagal S.G., Energy and Exergy Analysis of Coal Fired Power Plant, International Journal of Innovative Research in Technology & Science (IJIRTS), 53-57, 2015.*

3. *Singh S. P. and Vijay Kumar V., Exergy Analysis of the Turbine for a Reheat Regenerative 210 MW Fossil-Fuel based Power Plants in India, International Journal of Current Engineering and Technology. Vol.4, No.1, 2014.*

4. *Kumar K. and Mishra R. S., Thermodynamic (Energy-Exergy) Analysis Of Nine MW Coal Based Thermal Power Plant Using Entropy Generation Principle, American Journal of Engineering Research (AJER), Volume-6, Issue-7, pp-52-57, 2017.*

5. *Husnain N., Khan W. A., Qureshi S. R., Siddiqui F. A., Wang E. and Mehmood A, Exergetic and energetic analysis of a 210 MW Thermal Power Plant in Pakistan, Technical Journal, University of Engineering and Technology (UET) Taxila, Vol. 22 No. 1, 2017*

6. *Muhib Ali R., Abdul Ghafoor M. and Khanji H., Energy and Exergy Analysis of 210 MW Jamshoro Thermal Power Plant. Mehran University Research Journal of Engineering & Technology, Volume 35, No. 2, April, 2016.*

7. *Hafdhi F., Khir T., Ben-Yahyia A., Ben-Brahim A., Energetic and exergetic analysis of a steam turbine power plant in an existing phosphoric acid factory Energy, Conversion and Management 106 1230–1241, 2015.*

8. *Olaleye A. K., Wang M. and Kelsall G., Steady State Simulation and Exergy Analysis of Supercritical Coal-fired Power Plant with CO2 Capture, Elsevier. pp. 32–48, 2015.*

9. *Kumar R., Sharma A.K. and Tewari P. C., Thermal Performance and Economic Analysis of 210MWe Coal-Fired Power Plant. Hindawi Publishing Corporation, Journal of thermodynamics, Article ID 520183, http://dx.doi.org/10.1155/2014/520183, 2014.*

10. *Sarang G. J. and Amit Th. K., Exergy Analysis of Boiler in Cogeneration Thermal Power Plant, American Journal of Engineering Research (AJER), Volume 02, Issue 10, pp 385-392, 2013.*

11. *Kumar P.K., and Chandra H., Energy and Exergy Analysis of Boiler and Turbine of Coal Fired Thermal Power Plant, International Journal of Engineering Research and Technology (IJERT), Volume 02, Issue 06, pp 1428-1440, 2013.*

12. *Moran M.J. and Shapiro H.N., Fundamentals of Engineering Thermodynamics, sixth ed., John Wiley & Sons, Inc., 2006.*

13. *Nazrul Islam A.K.M., Alam F. and Ashraful Islam M., Energy and Exergy Analysis of a Coal Fired Thermal Power Plant with Varying Load Conditions. Journal of Scientific and Engineering Research, 4(7):215-229, 2017.*

14. *Sengupta S., Datta A. and Duttagupta S., Exergy Analysis of a Coal-based 210 MW Thermal Power Plant, International Journal Of Energy Research, Vol. 31, pp. 14–28, 2007.*

15. *Rosen M. and Dincer I., Therm-oeconomic Analysis of Power Plants: an Application to a Coal Fired Electrical Generating Station, Energy Conversion and Management, Vol. 44, pp. 2743-2761, 2003.*

16. *Mitrovic D., Zivkovic D. and Lakovic M., Energy and Exergy Analysis of a 348.5 MW Steam Power Plant, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, Vol. 32, pp. 1016 – 1027, 2010.*